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CARBIDE CUTTING TOOLS IN THE USSR

[N. H. Polakowski, author of the article summarized below, used the following sources: Machining Theory and Practice, American Society for Metals, Cleveland, 1950; Machining Standards for High-Speed Steel Tools, USSR Ministry of Machine-Tool Building, published by Mashgiz, Moscow, 1950; Encyclopedia of Machine Research, Vol 4, Mashgiz, Moscow, 1947; G. A. Preiss, High-Speed Machining of Metals, Mashgiz, Kiev, 1950; and A. P. Ivanov, "High-Speed Machining of Heat-Resistant Austenitic Steels," Stanki i Instrument, Vol 22, February 1951, p 3.

Tables and figures referred to are appended.]

High-Speed Steels and Cemented Carbides

Tungsten, molybdenum, and cobalt are rare in the USSR, but their use is more and more indispensable in the manufacture of jet motors. For this reason, range of high-speed steels has been reduced from five grades to two. The steel in general use, designated by the symbol El-262, contains only 8.5 to 10 percent tungsten, 2.5 percent vanadium, and 4 percent chromium. The "special" grade, RF-1, is the well-known 18-4-1 grade, and its use is limited to the manufacture of hobs with ground profiles, blades for cutting gears, screw taps, thread-milling cutters with ground threads, spindles, twist drills for steels with a hardness higher than Brinell 200, and some special tools.

Starting with the principle that the quantity of metal removed in machining, per unit of weight of the alloy element (tungsten) in the tool, is considerably more with carbides than with high-speed steels, the Soviets use carbide tools whenever possible. To this end, they are now producing a large variety of carbides, details on which are given in Table 2. The majority of these carbides have been produced since 1945; grade T30K4, containing 30 percent of titanium carbide, was created only in 1948 or 1949. Before 1941, only tungsten carbides could be found, known under the name of "Pobedit". They were all of inferior quality.

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Chemical composition and index of hardness of Soviet carbides are compa-
rable to those of materials manufactured in the US and in Europe. Symbols used
in the tables define the composition of the carbide, V representing tungsten
carbide, N nickel, K cobalt, and T titanium carbide. Thus VK8 designates a
material containing 8 percent of cobalt (K8), the rest being composed of tungsten
carbide (V); and T21K8 designates a material containing 21 percent titanium car-
bide (T21) and 8 percent cobalt (K8), the rest being tungsten carbide.

The basic speeds, feeds, and depths of cut for typical materials are deter-
mined in the USSR by the Office of Technical Standards of the Ministry of Machine-
Tool Building. Its investigations are correlated and results published in book
form, constituting the basis for computing minimum manufacturing time for machined
articles.

The materials taken as bases for calculation of speeds, feeds, and depths of
cut are an 80-kilogram-per-square-millimeter carbon steel, having a hardness of
approximately Brinell 215; a casting, of Brinell 190· a malleable casting, of
Brinell 150, and a bronze, of Brinell 100 to 140. For other materials, the speeds,
feeds, and depths of cut are calculated with simple formulas, substituting appro-
priate constants. Table 1 gives the cutting speed, in meters per minute, for the
turning of two of these materials. Table 3 indicates the power, in kilowatts, nec-
essary for machining 80-kilogram-per-square-millimeter steel. The time and power
used per cubic centimeter of metal removed can be calculated easily from these
tables.

Table 4 gives the values of some speeds, in meters per minute, chosen for
machining an 80-kilogram-per-square millimeter steel with a high-speed E1-262
steel tool. Although the speeds shown in the table are not indications of excep-
tional efficiency, the examples below of turning with negative-angle tools are in-
teresting, in particular from the viewpoint of the high speeds of cut which are
indicated.

Turning Tools With Negative Angle

Two standard carbide-grain tools, intended for general use in roughing and
finishing operations, are represented as (a) and (b) in Figure 1. These tools
have clearance angles which are entirely negative, while the tools represented in
Figure 2 have tips with negative angles in the area of the cutting edges combined
with secondary clearances at positive angles. The width of the tip with negative
angle is generally equal to the feed per revolution multiplied by 0.8 to 1.5.
These tools are represented as having the advantage, over tools with completely
negative clearance angles, of considerably reducing radial pressures and power
consumption. It would appear that the power necessary for machining with the help
of a tool having a totally negative clearance of 10 degrees is 25 percent higher
than that needed with a tool having a tip with a negative angle and a secondary
positive clearance of 15 degrees, and that the radial pressure is from 50 to 60
percent higher. It should be noted that similar results have been obtained in the
United States.

It would appear that speeds up to 1,035 meters per minute have been used for
machining bronze castings with the tool shown in (b) of Figure 2. However, the
carbide plate forming the nose of this tool being less resistant than those of the
tools in Figure 1, this type of tool is not recommended for interrupted cuts, as,
for example, in the turning of rough-forged castings.

With a tool similar to that represented in (a) of Figure 1, an annealed steel
containing 0.40 percent carbon and one percent chrome was turned at a speed of 505
meters per minute, with a feed of 0.30 to 0.40 millimeter per revolution and a
depth of cut of 10 to 12.5 millimeters. For finished-turning operations, using
feeds of 0.05 to 0.075 millimeter per revolution and depths of cut of 0.15 to 0.40
millimeter, the cutting speeds recommended are 300 to 150 meters per minute. The
highest speed is suitable for soft steel; the lowest speed is suitable for steels
having hardnesses of Brinell 200 to 250. T30K4 carbides are indicated for turning
steel.

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A turning tool of KBEK design is shown in Figure 3. It was designed for use on rigid and powerful machines exclusively. As a result of the small value of the angle ϕ , the area of contact of the tool on the casting is relatively great, so that despite the considerable amount of heat generated (30 percent more than with standard tools), the temperature of the edge would remain lower than that of tools of a different type. In practice, ϕ equals 10 to 20 degrees, ϕ' equals 10 to 15 degrees, and y equals minus 5 degrees. It would appear that on a steel of 0.45 percent carbon, with a cut one millimeter deep and a feed of 0.20 millimeter per revolution, a cutting speed of 965 meters per minute can be used. On a low-percentage alloy steel, known as "Chromansil," containing 0.40 percent carbon, one percent chromium, one percent manganese, and one percent silicon and treated to a tensile strength of 160 kilograms per square millimeter, turning speeds up to 168 meters per minute reportedly have been attained. For a laminated stainless steel of 80-87 kilograms per square millimeter, the speed of cut would be about 290 meters per minute, the depth of cut and the feed being identical in the three examples.

It is asserted that the type of tool represented in Figure 4 is particularly suitable for combined traversing and facing operations on short castings such as pinion blanks. In the shop, the turning speed used for a casehardened steel with one percent of chromium would be in the nature of 520 to 610 meters per minute, using a depth of cut of 2 millimeters and a feed of 0.23 millimeter per revolution. The same tool may likewise be used for dressing railroad-car buffers at a speed of 1,035 meters per minute, the depth of cut being one millimeter and the feed 0.70 millimeter per revolution. Such speeds are possible, however, only on operations of short duration because of the rapid heating of the tool. Concentric channels or grooves 2 millimeters deep and 20 millimeters apart are cut in the face of the 330-millimeter buffer so as to furnish cooling points; in this way the useful life of the tool lasts 60 minutes.

Machining of Hard Steels

In many cases, it is possible to replace grinding by turning, and consequently, to reduce costs considerably. In the case of an outside flange for ball bearings, 480 millimeters in diameter, a 50 to 60 percent time saving was effected in proceeding to finished turning in place of grinding after hardening to Rockwell C 62-63, the machining allowance of metal removed on the diameter being from 3 to 4 millimeters. A carbide-grain tool with negative angle, of VK8 grade, was used.

A similar tool was used for machining tempered-steel cylinders 1,750 millimeters in diameter and 2,450 millimeters long, for a cold rolling mill. These cylinders were hardened to Rockwell C 67. With a depth of cut of 0.50 millimeter to one millimeter, a feed of 0.40 millimeter per revolution, and a cutting speed of 28 to 30 meters per minute, the useful life of the tool between successive resharpenings was 100 minutes. For the turning of chrome steel cylinders having Rockwell hardness of C 63 to 65, using a T15K6 titanium carbide tool, it was possible to use a cutting speed of 60 meters per minute with a depth of cut of 0.30 to 0.40 millimeter and a feed of 0.25 to 0.30 millimeter per revolution.

With material of this kind, one can proceed effectively to machining only if the outside layer reaches a temperature of about 600 to 800 degrees centigrade, so that the metal in front of the nose of the tool is softened. The chip then comes off the casting in the form of a continuous spiral.

A very good surface finish is obtained, comparable to that obtained by grinding. It can be said that when one turns a steel in a softened state, the tangential force pulling the tool in a descending direction is greater than the radial force. It has been determined, in the course of machining hardened steels, that the radial force could be higher. The difference increases in proportion as the cutting speed increases, and, in some cases, the radial pressure can be two or three times higher than the tangential pressure. Consequently, the rigidity of mounting of the tool is of considerable importance.

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The best results with hardened steels have been obtained with the carbides VK8 and T5K10, which have sufficient toughness. For very fine finishing, carbides with a high titanium content (T15K6) can be used. Recommended cutting angles are given in Table 5, in which the reference letters correspond with those in Table [Figure ?] 1.

Characteristic cutting speeds and feeds for various depths of cut, used for turning carbon steel treated to a Rockwell hardness of C 46, are given in Table 6.

Machining of Heat-Resistant Austenitic Steels

The following results are obtained for high-content nickel-chrome steels, containing 0.30 to 0.50 percent carbon. One of these steels, designated as EYa2S, contains 0.30 to 0.40 percent carbon, 23 to 27 percent nickel, and 16 to 20 percent chromium. Another steel, type E169, contains about 0.50 percent carbon, 14 percent nickel, 14 percent chromium, and 2 percent tungsten. It was not possible to verify the exact composition of a third steel, designated E1388, which, nevertheless, belongs without any doubt to the same class. It should be noted that, although differing in carbide content (Table 1), designations of Soviet alloy steels do not define their composition.

The most appropriate turning tool for machining these steels has a tip with negative angle and a positive secondary clearance, similar in this to the tools in Figure 2. Using the same designation as in Figure 1, angles are as follows: Φ equals 45 degrees, Φ_1 equals 10 degrees, α equals 12 to 14 degrees, and γ equals 14 degrees. The width of the tip with 6-degree negative angle is 1.5 millimeters.

A series of machinability tests allows schematization of results obtained as shown in Figure 5. For any cutting speed, the useful life of the tool depends primarily on the feed. If a certain feed per revolution be exceeded, the useful life decreases rapidly. The limits of feed and the life of tools between successive regrindings are as follows:

Cutting speed (meters per min)	Feed (mm per revolution)	Useful Life (min)
150		
	0.16	
200		100
	0.11	
250		85
	0.075	
		55

It has been established that the cutting speed V and the useful life T are given by the formula $V = C_v/T^m$.

The constant C_v varies from 3,700 to 4,700 according to the types of steel, and the exponent m varies from 0.1 to 0.46. For low-grade nickel-chrome steels the value of this exponent varies from 0.1 to 0.2.

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Table 1. Cutting Speeds in Meters per Minute
for Machining 80 Kg/Sq Mm Steel and Cast Iron With Carbide Tools

Material	Tool	Depth of Cut (mm)	Feed - mm per revolution			
			0.40	0.70	1.00	1.40
80 kg/sq mm Steel	T5K10	4	100	80	72	64
		8	87	72	65	57
		15	77	63	58	48

			Feed - mm per revolution			
			0.10	0.25	0.50	1.00
	T15K6	1	270	223		
		2		198	160	
		4		175	140	112
		8			123	100

			Feed - mm per revolution				
			0.10	0.25	0.50	1.00	2.00
Casting Brinell 190	VK8	1	122	103			
		2		94	81		
		4		84	68	52	36*
		8			59	45	34
		15			54	41	31

* For a 6-mm depth of cut

Table 2. Composition of Cemented Carbides Produced in the USSR

Grade	Composition (%)				Rockwell C Hardness
	Tungsten Carbide	Titanium Carbide	Cobalt	Nickel	
VK3	97		3		89
VK6	94		6		87.5
VK8	92		8		87.5
VK12	88		12		86.5
VN6	94			6	87.5
T5K6	89	5	6		88

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Grade	Composition (%)				Rockwell C Hardness
	Tungsten Carbide	Titanium Carbide	Cobalt	Nickel	
T5K10	85	5	10		88
T15K10	79	15	6		87.5
T21K8	71	21	8		88
T30K4	66	30	4		90

Table 3. Power in Kilowatts Necessary for Machining 60 Kg/Sq Mm Steel With T15K6 Carbide

Depth of Cut (mm)	Feed - mm per revolution			
	0.10	0.25	0.50	1.00
1	1.50	2.50		
2			4.20	5.90
4		7.60	10.40	14.00
			18.40	25.00

Table 4. Cutting Speeds in Meters per Minute for Machining 60 Kg/Sq Mm Steel With High-Speed Steel E1-262

Depth of Cut (mm)	Feed - mm per revolution			
	0.10	0.25	0.40	1.00
1	96	71		
2		55	44	
4			37	20
8				17

Table 5. Tool Angles Recommended for Machining Steels of Various Hardnesses (See Figure 1)

Rockwell C Hardness of the Steel to be Machined	Tool Angles (degrees)				Radius of the Tool Nose (mm)
	γ	α	ϕ	ϕ_1	
40-50	10	12-14	40	15	1-1.5
50-60	10		30	12	
60-65		10-20	25-20	10	

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Table 6. Cutting Speeds in Meters per Minute for Machining
a Carbon Steel With a Hardness of Rockwell C46

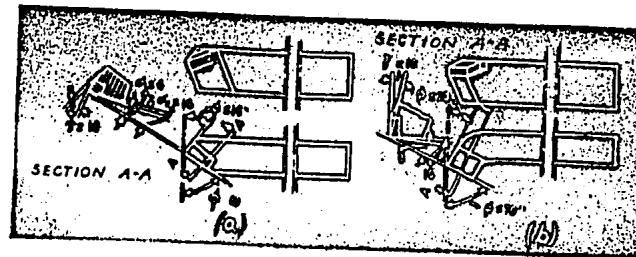| Depth of Cut (mm)	Feed – mm per revolution		
	0.05	0.15	0.30
0.20	109	82	67
0.50	91	62	47
1.00	86	52	37
2.00	68	35	24

[Figures follow.]

Figure 1. Two Examples of Turning Tools
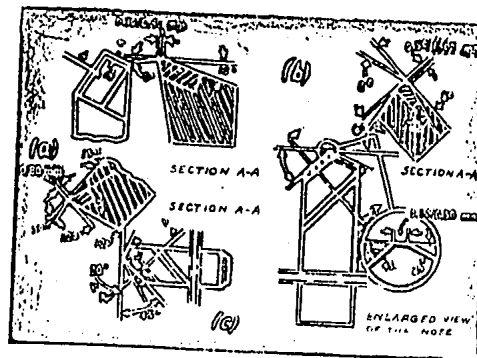for General Use, With Negative Angle

Figure 2. Examples of Turning Tools
With Negative-Angle Tips

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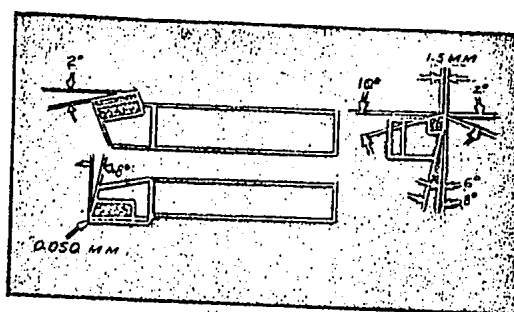
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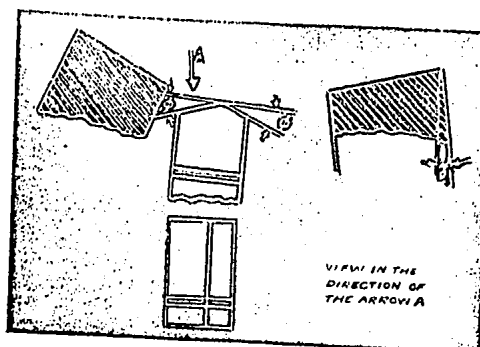
Figure 3. KBEK Turning Tool

Figure 4. Traversing and Facing Tool
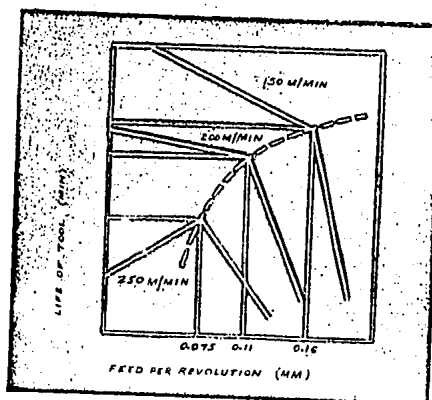
Figure 5. Relation Between Feed and Useful Life of Tool in Machining
Austenite Steels at Various Speeds

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